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ANALYSIS OF DELIVERY ACCURACY FOR AH-1G (COBRA) LAUNCHED 2.75-INCH ROCKETS FROM TESTS CONDUCTED APRIL-MAY 1971 AT CHINA LAKE, CALIFORNIA

B. R. Billman

Army Armament Command
Rock Island, Illinois

March 1975

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B.P BILLMAN

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SYSTEMS ANALYSIS OFFICE
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The purpose of this study was to determine the dispersions of standard MARK 40, MARK 40 with 20 degree bent fins, and standard MARK 4 2.75-Inch rockets when launched in pairs from an in-flight AH-1G/Cobra.

Dispersions of the standard MK40 and MK40 with bent fins are approximately equal. Dispersions of the MK40 are significantly higher.

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SUMMARY

The purpose of this study was to determine the dispersions of standard MARK 40, MARK 40 with 20 degree bent fins, and standard MARK 4 2.75-inch rockets when launched in pairs from an in-flight AH-1G/Cobra. Data from firing tests, sponsored by the Project Manager for the 2.75-Inch Rocket System and conducted by the Naval Weapons Center, China Lake, California, were subjected to analysis. Dispersion was characterized by two distributions: (1) the distribution of rocket impacts about the mean-point-of-impact (MPI) and (2) the distribution of MPI's about the target. Estimates of the standard deviations of these distributions were used as measures of the characteristic disperions of the three rockets.

Dispersions of the standard MK 40 and the MK 40 with bent fins are approximately equal. Standard deviations of impacts about the MPI vary from approximately 3.5 to 4.5 mils in elevation and 3.5 to 10.0 mils in deflection. Standard deviations of MPI's about the target vary from about 6.5 to 9.5 mils in elevation and 8.0 to 16.0 mils in deflection. Dispersions of the MK 4 are significantly higher. Impacts about the MPI are approximately 16.0 mils in both elevation and deflection, and standard deviations of MPI's about the target are approximately 17.0 and 30.0 mils, respectively, in elevation and deflection.

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PREFACE

This study was authorized by the Director, US Army MUCOM Operations Research Group pursuant to a program for general systems analysis support requested by the Project Manager for the 2.75-Inch Rocket System. The systems analysis support effort has focused on the delivery accuracies and effectiveness potentials of various launcher/rocket/warhead configurations fired from attack helicopters.

This report was part of a series of tests and analyses to assess error sources governing the dispersion and accuracy of helicopter-delivered 2.75-inch rocket patterns. Work was begun in July 1971 and completed in October 1971 and results were transmitted to the Office of the Project Manager in the course of the analysis. This report has been prepared in order to provide a record of the rationale and scope of the analytical effort as well as dispersion and accuracy information derived from these tests.

The study was completed by the US Army MUCOM Operations Research Group; finalization of the study report was accomplished by its successor, the ARMCOM Systems Analysis Office.

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CONTENTS

FIGURES

FIGURES (Continued)

TABLES

INTRODUCTION

OBJECTIVE

The objective of this analysis was to obtain estimates of dispersion and accuracy from impact data of 2.75-inch rockets launched in pairs from an AH-1G/Cobra helicopter. This data was derived from a series of tests conducted at the Naval Weapons Center, China Lake, California during April and May 1971. These tests were sponsored by the Project Manager for the 2.75-Inch Rocket System.

BACKGROUND

The purpose of these tests was to establish the delivery accuracy and rocket pattern characteristics of AH-1G/2.75 inch rocket configurations and to assess the potential gains in operational effectiveness implicit in improved delivery techniques. The purpose of one of these tests was to compare the dispersion characteristics of standard Mark 40, the Mark 40 equipped with 20 degree bent fins, and standard Mark 4 rockets launched in pairs from an AH-1G Cobra aircraft in forward flight[1]. The analysis in this report was based on the data resulting from this test.

SUMMARY OF TEST PROCEDURES

During testing, the attack aircraft was directed by range control via radio to a specific spatial position in relation to the target tank. At this point, the pilot was informed of his correct range and altitude and was released to fire. Aircraft position was determined by radars which fed data to an on-site computer. Coordinates of the aircraft position in relation to the target were recorded and plotted at intervals of 0.01 second. A tone generator, activated upon rocket launch, was used to identify the time (and position) of launch. Pilots were instructed to attempt to hit the target by firing pairs of rockets (i.e., one rocket from each of two pods simultaneously) while maintaining a constant flight profile. Any number of pairs of rockets could be launched during a given attack. Immediately following each attack, ground-range personnel identified, marked, and recorded the location of each impact. Impact locations and their sequence were also recorded by cameras within the attack aircraft, cameras within an aircraft directly over the target tank, and several ground-located cameras. Two pilots were used. Both had

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[1] Ltr from Naval Weapons Center (5562-DKA:BP) to Director, USAMUCOM ORG, dtd 4 June 1971, subject: 2.75-Inch Rocket, AH-1G (COBRA) Accuracy Demonstration, (UNCLASSIFIED).

extensive flying experience and both had combat experience with the AH-1G/ rocket system. Additionally, the pilots were permitted practice trials prior to the tests and were permitted firing passes for sight calibration following periods of refueling and rearming during the testing. Further details of the test and data collection procedures are provided in Appendix A.

APPROACH

ASSUMPTIONS

The following assumptions governed the analysis of test data:

a. During testing, the pilots attempted to adjust fire by observing the burning in-flight rockets, making estimates regarding their expected points of impact, and correcting the aim point accordingly.

b. When projected into the plane normal to the line of sight and converted to angular measure, impact points of rockets launched in pairs under identical launch conditions were normally distributed in both elevation and deflection about their mean-point-of-impact (MPI).

c. When projected into the plane normal to the line of sight and converted to angular measure, the MPI's of pairs of rockets, launched during a single attack in which the flight profile is constant, were normally distributed in both elevation and deflection about the projected target center.

MEASURES OF DISPERSION AND ACCURACY

The following measures of accuracy and dispersion were employed:

a. The standard deviation of the distribution of impacts about the MPI was denoted by σ_1 and was defined as the error about the MPI. Values of σ_1 for rockets launched in pairs were the best indicators obtainable from available test data of inherent rocket dispersion.

b. The standard deviation of the distribution of MPI's about the target center was denoted by σ_2 and was defined as the error of the MPI.

c. The standard deviation of the distribution of impacts about the target was denoted by $\bar{\sigma}$ and was used synonymously with both systems error and systems accuracy.

DATA ANALYSIS PROCEDURE

For the purpose of analysis, test data were separated into two groups as follows:

Group 1. Data representing firings for which both the sequence of launch and impact were determined and for which the aircraft position relative to the target at launch was recorded.

Group 2. Data representing firings for which the launch and impact sequence were not identified and for which the aircraft position relative to the targets was recorded only at the start and stop fire points.

For both data groups, impact points were translated from the ground plane to a coordinate system in the plane normal to the line-of-sight; therefore, all measures of accuracy and dispersion relative to elevation (or range) are in the plane normal to the line-of-sight.

For Group 1 data, estimates of the standard deviations of the distribution of impacts about the MPI, the distribution of MPI's about the target center, and the distribution of impacts about the target center were derived for each rocket motor type and each flight profile. To the extent practical, the resultant estimates were examined statistically (primarily through the use of the "F" variance ratio) to gain insights into the significance of the test-to-test variations and the validity of pooling data.

For Group 2 data, estimates of the standard deviations of the distribution of impacts about the MPI and the distribution of impacts about the target center were based on the launch position represented by the mid-point of recorded start and stop-fire aircraft positions.

RESULTS AND DISCUSSION

GROUP 1 DATA

Distribution of Impacts About the MPI

Estimates of standard deviation, representative of the distributions of impacts about the MPI for each Group 1 flight, are shown in Table 1.

TABLE 1. ESTIMATED STANDARD DEVIATIONS OF THE DISTRIBUTION OF IMPACTS ABOUT THE MPI (σ_1) - BY FLIGHT - GROUP 1

Flight Number[a]	Rocket Motor	Delivery Profile	Number of Impacts	Standard Deviation (mils) Elevation	Deflection
4	MK 40 w/Bent Fins	High Angle	24	4.8	6.9
5	MK 40 w/Bent Fins	High Angle	28	3.6	3.5
6	MK 40 w/Bent Fins	Low Angle	28	3.7	7.0
7	MK 40 w/Bent Fins	Low Angle	26	2.9	6.9
11	MK 40 w/Bent Fins	High Angle	16	4.2	6.8
13	MK 4	High Angle	26	16.0	14.0
15	Standard MK 40	High Angle	20	3.7	3.7
16	Standard MK 40	Low Angle	22	3.4	9.8

[a]Flight numbers assigned during process of testing.

An apparent anomaly occurs at the outset with respect to Flights 4, 5 and 11. While statistical tests indicate that the standard deviations in elevation for those trials may be grouped to obtain a common estimate, the deflection error for Flight 5 is significantly lower (i.e., at the 1% level as based on the "F" statistic) than the corresponding values of Flights 4 and 11. Since the data provided in Appendix A does not reveal any aspects of Flight 5 which would distinguish that trial from Flights 4 and 11, there is no basis for treating the three tests as other than "replications" (in a statistical sense). In that context, the test-to-test variability is considered indicative of the actual variability to be

expected for an operation involving high angle delivery of rockets with modified MK 40 motors as represented by the test conditions. This is not to imply that a causative factor did not exist for the reduced dispersion in deflection recorded in Flight 5, but only that such a factor could not be identified from analysis of the data. As an extension of the thesis that the three trials be treated as "replications", the standard deviations were pooled to obtain "representative" estimates of dispersion for elevation and deflection. The two tests for low angle delivery (viz., Flights 6 and 7) involving modified MK 40 rocket motors were similarly combined, but, in this case, the procedure was compatible with statistical tests, showing no significant differences. The pooled estimates of σ_1 for the MK 40 with bent fins, together with the values derived from the single flights with the standard MK 40 and MK 4, are summarized in Table 2. With respect to the MK 4, the considerably greater dispersion produced by that rocket motor is clearly evident as compared to all results for the standard and modified MK 40.

Distribution of MPI's About the Target

The dispersion estimates for the MPI's about the target, σ_2, are presented in Table 3 for each flight in Group 1. For these reasons, statistical tests indicate a possible anomaly in the elevation values for

TABLE 2. ESTIMATED STANDARD DEVIATION OF THE DISTRIBUTION OF IMPACTS ABOUT THE MPI (σ_1) - BY MOTOR TYPE AND DELIVERY PROFILE - GROUP 1

Rocket Motor	Number of Impacts	Delivery Profile	Standard Deviation (mils) Elevation	Deflection
Standard MK 40	20	High Angle	3.7	3.7
	22	Low Angle	3.4	9.8
MK 40 w/Bent Fins	68	High Angle	4.3	5.6
	54	Low Angle	3.3	7.0
MK 4	26	High Angle	16.0	14.0
	--	Low Angle	Data Unavailable	

TABLE 3. ESTIMATED STANDARD DEVIATIONS OF THE DISTRIBUTION OF MPI's ABOUT THE TARGET (σ_2) - BY FLIGHT - GROUP 1

Flight Number	Rocket Motor	Delivery Profile	Number of MPI's	Standard Deviation (mils) Elevation	Deflection
4	MK 40 w/Bent Fins	High Angle	12	7.6	9.1
5	MK 40 w/Bent Fins	High Angle	14	8.6	14.1
6	MK 40 w/Bent Fins	Low Angle	14	9.7	10.0
7	MK 40 w/Bent Fins	Low Angle	13	4.7	7.3
11	MK 40 w/Bent Fins	High Angle	8	11.2	10.8
13	MK 4	High Angle	13	17.2	30.0
15	Standard MK 40	High Angle	10	9.3	16.0
16	Standard MK 40	Low Angle	11	6.5	7.7

Flights 6 and 7. However, the same logic noted above in connection with the pooling of the σ_1 estimates for Flights 4, 5 and 11 would pertain also to this case. Accordingly, Table 4 has been constructed to correspond to Table 2. It should be noted that, in addition to the markedly greater dispersion of the rockets about the MPI (viz., σ_1), the MK 4 also exhibits considerably larger standard deviations of the MPI's about the target in comparison to all MK 40 trials.

TABLE 4. ESTIMATED STANDARD DEVIATIONS OF THE DISTRIBUTION OF MPI's ABOUT THE TARGET (σ_2) BY MOTOR TYPE AND DELIVERY PROFILE - GROUP 1

Rocket Motor	Number of MPI's	Delivery Profile	Standard Deviation (mils) Elevation	Deflection
Standard MK 40	10	High Angle	9.3	16.1
	11	Low Angle	6.5	7.7
MK 40 w/Bent Fins	34	High Angle	9.4	11.8
	27	Low Angle	7.7	8.8
MK 4	13	High Angle	17.2	30.0
	--	Low Angle	Data Unavailable	

Distribution of Impacts About the Target

If impacts are normally distributed about the target, the standard deviation (denoted $\overline{\sigma}$) of the distribution is approximated by the root-mean-square (RMS) of the independent estimates of σ_1 and σ_2. For comparison purposes, estimates of $\overline{\sigma}$ for each flight derived by the RMS approximation and by application of the impact data directly are shown in Table 5. With the exception of Flight 5, the two techniques yield essentially the same results. The excellent agreement for all but Flight 5 was considered sufficient validation to permit application of the RMS method for estimating total system delivery error. With the RMS approximation, estimates of $\overline{\sigma}$ were derived for each motor type and delivery profile as presented in Table 6.

TABLE 5. COMPARATIVE ESTIMATES OF TOTAL SYSTEMS ERROR ($\overline{\sigma}$) - BY FLIGHT - GROUP 1

			Total System Error (mils)			
			RMS Method		Impact Data	
Flight Number	Rocket Motor	Delivery Profile	Elev	Defl	Elev	Defl
4	MK 40 w/Bent Fins	High Angle	9.0	11.4	9.5	11.4
5	MK 40 w/Bent Fins	High Angle	9.6	14.5	11.4	11.6
6	MK 40 w/Bent Fins	Low Angle	10.7	12.2	10.8	12.3
7	MK 40 w/Bent Fins	Low Angle	5.5	10.1	5.6	10.5
11	MK 40 w/Bent Fins	High Angle	13.2	11.8	13.5	12.0
13	MK 4	High Angle	23.5	33.2	23.5	33.3
15	Standard MK 40	High Angle	10.1	16.5	10.4	17.1
16	Standard MK 40	Low Angle	7.4	12.5	7.6	12.3

TABLE 6. ESTIMATED STANDARD DEVIATIONS OF THE DISTRIBUTION OF IMPACTS ABOUT THE TARGET ($\overline{\sigma}$) - BY MOTOR TYPE AND DELIVERY PROFILE - GROUP 1

Rocket Motor	Number of Impacts	Delivery Profile	Standard Deviation (mils) Elevation	Deflection
Standard MK 40	20	High Angle	10.1	16.5
	22	Low Angle	7.3	12.5
MK 40 w/Bent Fins	68	High Angle	10.4	13.4
	[illegible]4	Low Angle	8.6	11.5
MK 4	26	High Angle	23.4	33.1
	--	Low Angle	Data Unavailable	

Adjustment of Aim During Attack

The Group 1 data provides an opportunity to examine the extent to which pilot adjustments, during the firing sequence, influence accuracy. If the pilot can successfully adjust fire by launching successive pairs of rockets and observing their flight towards the target, the angular separation distances of the MPI and the target will decrease with successive pairs of rockets launched during the attack. The angular separation distances in elevation and in deflection between the MPI and the target for first pairs versus second pairs of rockets are shown, respectively, in Figures 1 and 2. Analogous data for second pairs versus third pairs are shown in Figures 3 and 4. In Figures 1 and 2, if the separation distance of the MPI and target for the first pair is greater than that of the second pair, the representative point appears in the area below the 45-degree line. Similarly, if the second pair miss-distance is greater than that of the third pair, the representative point appears below the 45-degree line in Figure 3 and 4. There are no apparent differences of miss-distances of first and second pairs; the number of points above and below the 45-degree line are approximately equal. The data portrayed in Figures 3 and 4 show some tendency for the miss-distances of third pairs to be less than those of second pairs in deflection. However, it is apparent that a consistent trend toward a marked improvement in accuracy did not occur during the initial three rocket launches. Results for the first three pairs were considered sufficiently indicative of the accuracy picture for the conditions of test, and the matter of aim adjustment was not probed further.

GROUP 2 DATA

Sources of impact data for the Group 2 analysis are shown in Table 7. Flights 12 and 14 are the principal trials for which ground impacts could not be correlated with aircraft positions during the firing sequence. Inspection of the test data, tabulated in Appendix A, reveals that Pass 3 of Flight 14 probably involved ripple delivery. The total firing time showed 1.7 seconds for a pattern of 17 recorded impacts.

TABLE 7. SOURCES FOR GROUP 2 DATA

Flight Number	Rocket Motor	Delivery Profile	Pass	Number of Impacts
11	MK 40 w/Bent Fins	High Angle	2	4
			3	9
12	MK 40 w/Bent Fins	Low Angle	4	17
			5	13
13	Standard MK 4	High Angle	1	4
14	Standard MK 4	Low Angle	2	10
			3	17
15	Standard MK 40	High Angle	4	5

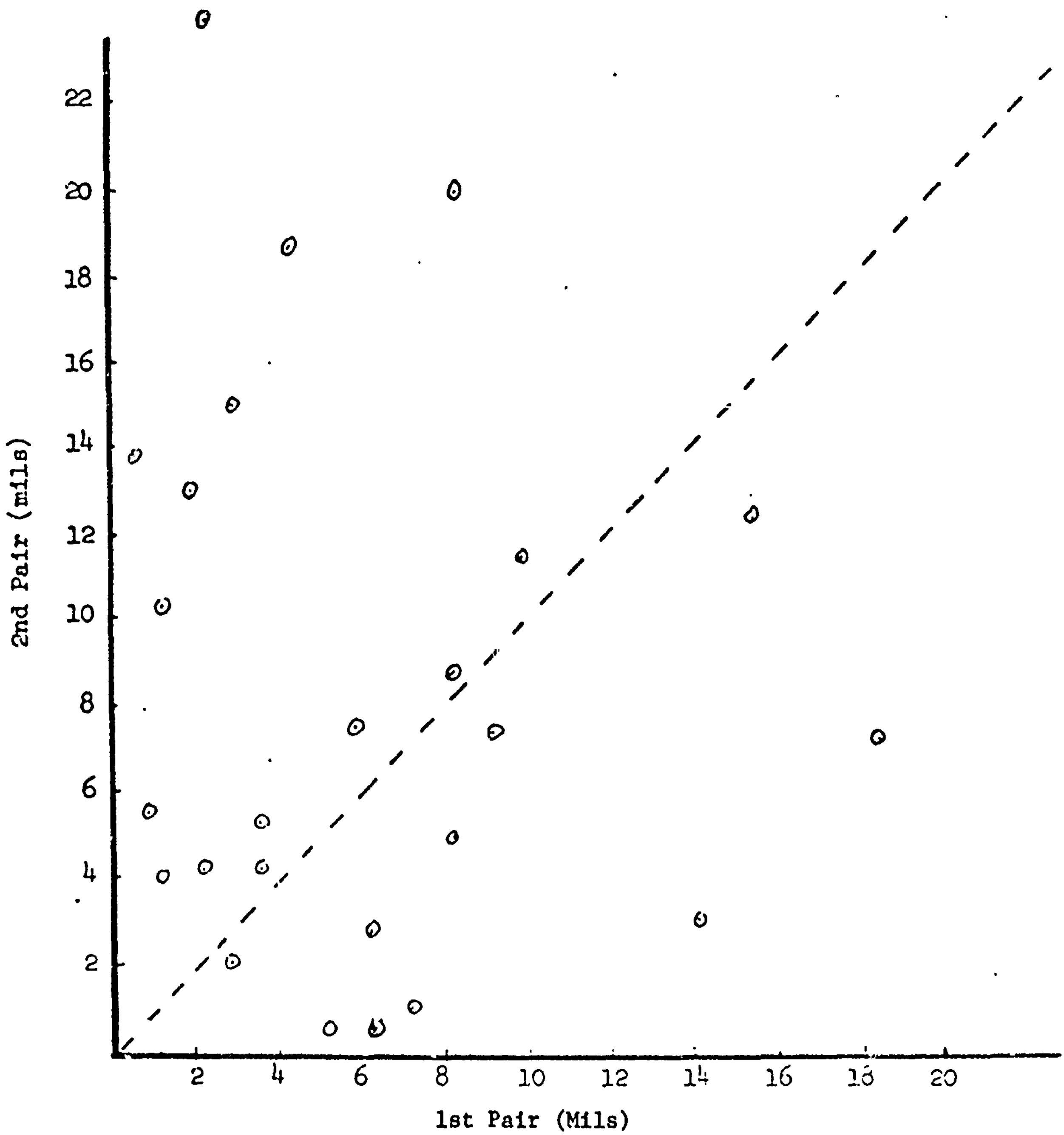

Figure 1. Angular Separation Distance in Elevation of the MPI and Target - 1st and 2nd Pairs - Group 1

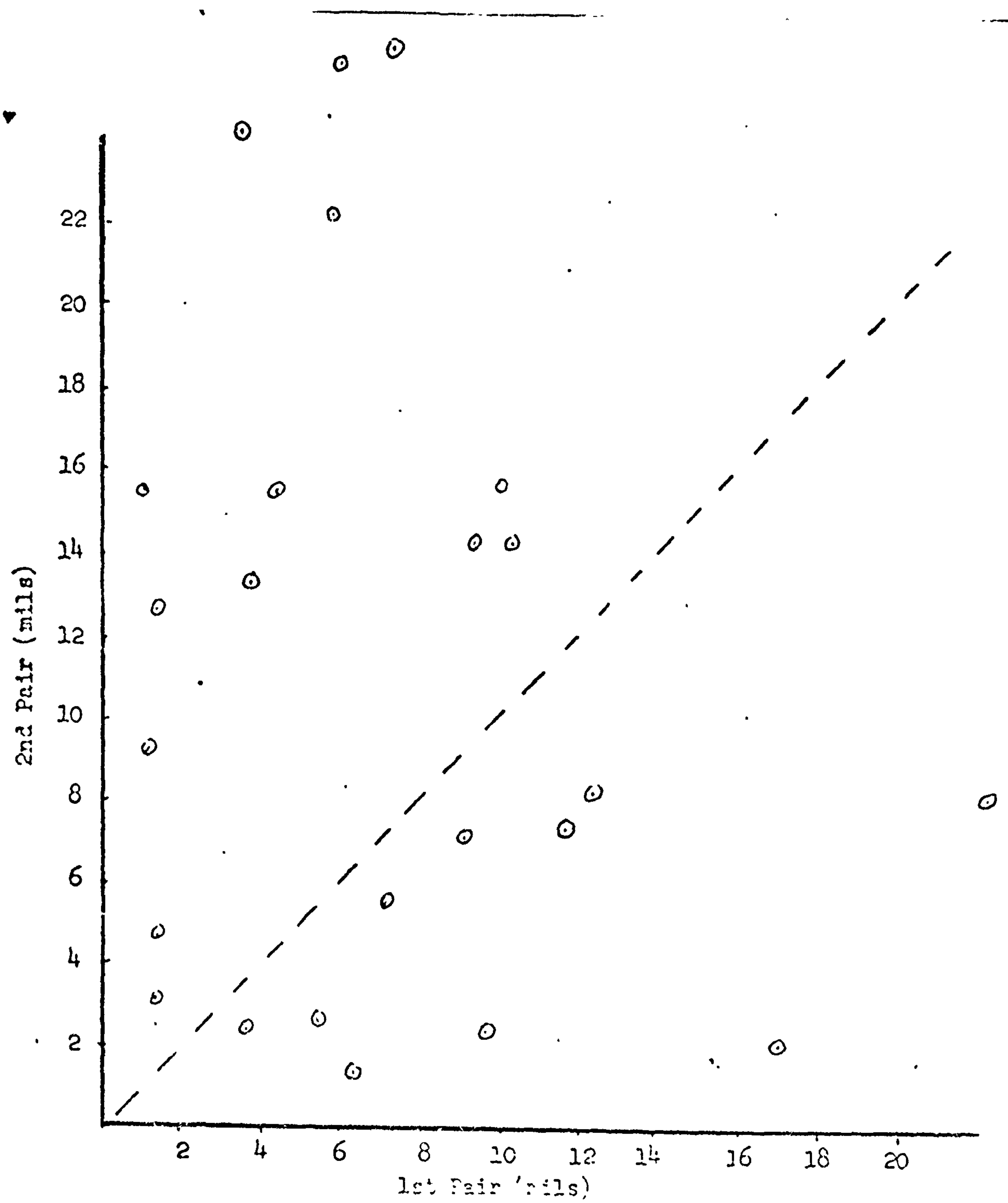

Figure 2. Angular Separation Distance in Deflection of the MPI and Target - 1st and 2nd Pairs - Group 1

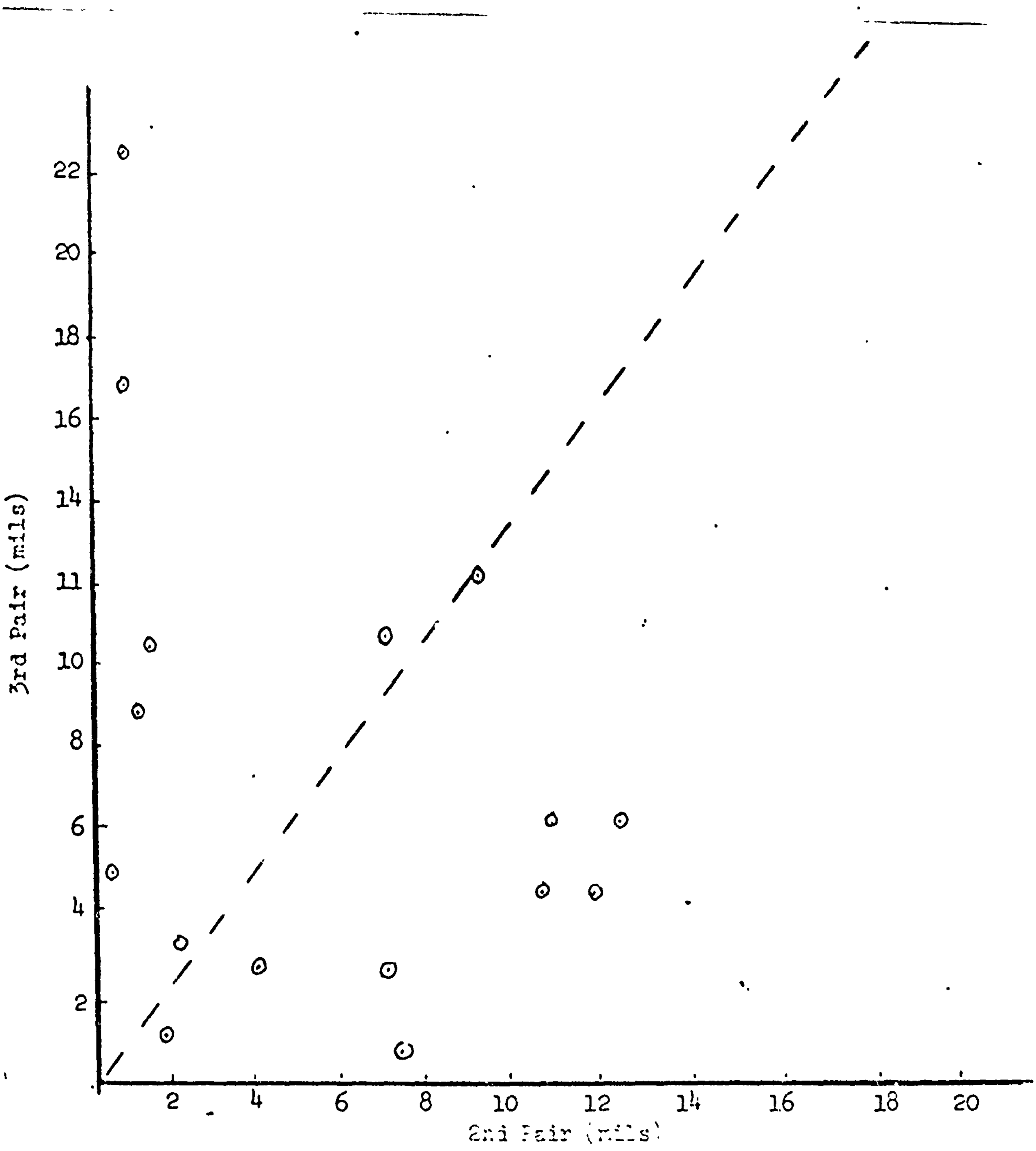

Figure 3. Angular Separation Distance in Elevation of the MPI and Target - 2nd and 3rd Pairs - Group 1

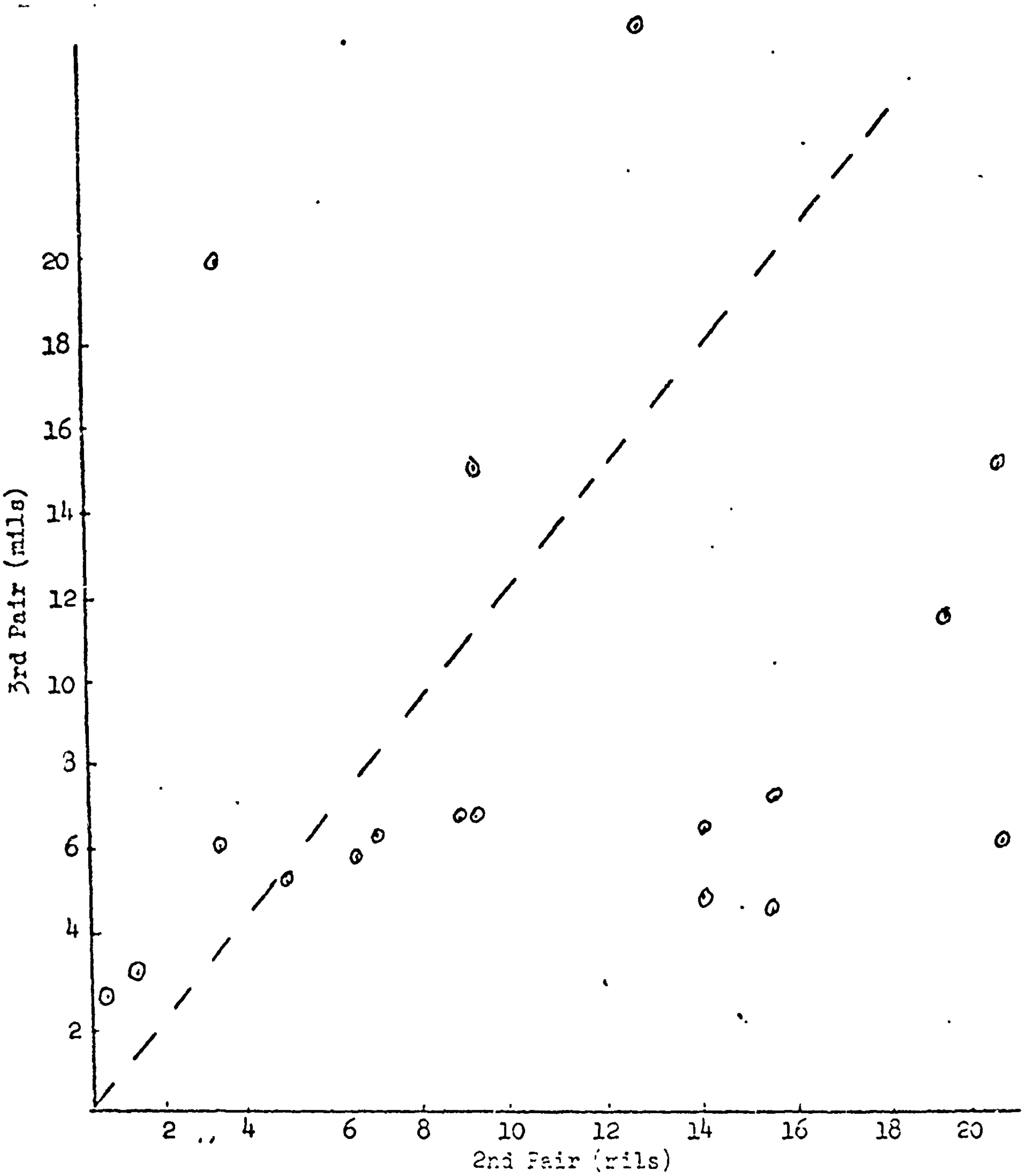

Figure 4. Angular Separation Distance in Deflection of the MPI and Target - 2nd and 3rd Pairs - Group 1

Distribution characteristics were inferred in terms of impacts about both the designated target and the overall mean-point-of-impact. Results for the two cases are presented in Table 8. Comparison of the two sets of results for the target and overall MPI, respectively, as reference reference points shows only the discrepancy for the standard Mark 40 delivered at the high attack angle to be of sufficient magnitude to indicate a lateral aiming bias. By definition, the standard deviations of impacts about the target represent the systems errors.

TABLE 8. ESTIMATED STANDARD DEVIATION OF THE DISTRIBUTION OF IMPACTS ABOUT THE TARGET AND THE DISTRIBUTION OF IMPACTS ABOUT THE PATTERN MPI - GROUP 2

Rocket Motor	Number of Impacts	Delivery Profile	Standard Deviation (mils)			
			Impacts about Target		Impacts about MPI	
			Elevation	Deflection	Elevation	Deflection
Standard MK 40	5	High Angle	6.3	29.4	6.3	19.1
	-	Low Angle	-	Data Unavailable		-
MK 40 w/ Bent Fins	13	High Angle	11.5	8.3	11.5	7.9
	30	Low Angle	9.6	8.4	9.3	8.2
MK 4	4	High Angle	13.9	15.7	13.9	14.1
	27	Low Angle	14.1	17.2	14.1	19.6

CONCLUSIONS

Comparisons of the systems errors derived from the reduction of the Group 1 and Group 2 data (as presented in Tables 6 and 8, respectively) are reasonable only in the case of the MK 40 with bent fins. In the other cases, either corresponding data are not available, or the Group 2 sample size is too small. The most significant apparent discrepancies between the sets of data are the 5 and 3 mil differences in deflection for high and low angle delivery, respectively. It is unclear whether the smaller Group 2 deflection errors are indicative of real reductions in dispersion and/or accuracy (as a result of differences in delivery profiles and firing rates) or are solely consequences of differences in analytical procedures used for the two data categories. Although the matter of the differences between the data groups could be pursued further (such as comparing effectiveness potentials for specific attack situations), such effort is not warranted from the standpoint of the ultimate utility of the Group 2 data. The Group 2 data could only serve as an order-of-magnitude check of the more precise Group 1 results for total systems error to detect any major discrepancies or anomalies which could arise from the data acquisition or computational procedures. Since the differences, noted above, do not suggest serious questions concerning the validity of the Group 1 dispersion and accuracy measures, those results can be accepted as representative of the delivery conditions under which the impact data were obtained.

The principal contributions of the tests to the data base are the error components derived from the Group 1 data. The ability to partition the systems errors into measures of basic dispersion and delivery accuracy is a fundamental requirement for effectiveness studies of fire control and stabilization systems which have differing effects on the two error components. However, the Group 1 data must be considered specific to the limited delivery conditions of the tests. Additional trials are required for other attack profiles and firing rates to establish a data base of sufficient breadth and applicability for the aforementioned effectiveness studies of systems engineering concepts and options.

In view of the statistical questions raised previously, there is no logical basis for pooling the Group 1 results over either rocket motor type (viz., standard and modified MK 40 motors) or delivery profile[2]. Accordingly, the results presented in Tables 2, 4 and 6 are the recommended values to be used for inherent dispersion (σ_1), error of the MPI (σ_2) and total systems error ($\overline{\sigma}$), respectively.

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[2] In a prior preliminary evaluation, of the data, Group 1 results for the standard and modified MK 40 motor were pooled for each delivery profile. Although the pooled estimates for σ_1 (viz., 3.6 mils in elevation and 7.7 mils in deflection) are noted in MUCOM ORG Report 46, Comparative Effectiveness of Competitive Motors for Helicopter-Launched 2.75-Inch Rockets, May 1973 -- CONFIDENTIAL Report, page 50, the values were used only in a discussion of comparative orders-of-magnitude from different tests and did not enter directly into the effectiveness computations performed for that study.

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APPENDIX A

TEST PROCEDURES AND RECORDED DATA

CONTENTS

TABLES

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TEST PROCEDURES AND RECORDED DATA

TEST PROCEDURES

All rockets were launched in pairs. The time between launch of pairs, the number of rockets per pass, and the number of passes per flight were the pilot's option. All flights of a given profile were conducted by one pilot. A typical flight was conducted as follows: range control directed the pilot to a specific range and altitude from the target. When he reached the correct range and altitude, rnage control commanded him to fire. The pilot was instructed to launch rockets in pairs and to follow, as nearly as possible, the flight path indicated by ground target centerline range markers. Sight settings prior to the pass and use of the sight during the pass were pilots' options. The pass was terminated by command from range control when the aircraft-to-target slant range was reduced to approximately 700 meters. Upon completion of a pass, range control again directed the pilot to the starting point, and the procedure was repeated. This process continued until the number of rockets allocated for the flight was expended.

Rocket pods were aligned and boresighted prior to testing; however, quadrant elevations used are unknown. Sight settings actually employed during testing were not recorded and rocket lot numbers are unknown. Flight configurations used are shown in Table A-1. Mean air-speed was 120 knots during low-angle flights and 130 knots during high angle flights. Line-of-sight from the launch position to the target at the time of launch varied from -3 to -7 degrees during low-angle delivery and from -11 to -24 during high-angle delivery. Delivery slant range varied from 2200 to 4000 feet and from 2800 ro 5000 feet during low- and high-angle flights, respectively.

TABLE A-1. FLIGHT PROFILES AND ROCKET MOTORS USED DURING TESTING

Flight Number	Flight Profile	Type Rocket Motor
4	High Angle	MK 40 with Bent Fins
5	High Angle	MK 40 with Bent Fins
6	Low Angle	MK 40 with Bent Fins
7	Low Angle	MK 40 with Bent Fins
11	High Angle	MK 40 with Bent Fins
12	Low Angle	MK 40 with Bent Fins
13	High Angle	MK 4
14	Low Angle	MK 4
15	High Angle	Standard MK 40
16	Low Angle	Standard MK 40

DATA COLLECTION

The aircraft position with respect to the target was recorded by radars which fed data to an on-site computer. Coordinates of the aircraft launch position were recorded by virtue of a tone generator activated upon the launch signal. Rocket impact points were located and identified by numbered markers denoting flight, pass, and sequence by ground-range personnel immediately following each pass. Impacts were also recorded by cameras within the test aircraft, by ground cameras, and by an overhead photoship. Coordinates of the test aircraft launch position and the rocket ground impacts were recorded with reference to the target center.

TEST DATA

Data resulting from the test are tabulated in Table A-2. All coordinates are given in feet and time in seconds. Aircraft spatial positions are denoted by X, Y, and H; respective positive values represent east, north, and above the target. Slant range from the launch point to the target is denoted by SRTC. Impact coordinates of the two rockets of a pair are denoted x_1, y_1, and x_2,y_2. Positive values of x and y represent impacts east and north of the target tank. For those cases in which the impact sequence of pairs could not be distinguished, only start and stop fire aircraft positions are recorded. Pairs denoted by "C" were launched for sight calibration.

TABLE A-2. TABULATION OF TEST DATA

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch				Rocket Impact Coordinates			
			X	Y	H	SRTC	X1	X2	Y1	Y2
	Flight No. 4, 8 April 1971, MK-40 with 20° Short Bent Fins									
1	1C	5.91	-99	-4506	978	4612	5	47	-130	-30
	2C	10.51	-74	-3535	797	3624	20	41	-75	303
2	1	8.35	-221	-3952	924	4064	21	-23	101	-28
	2	9.68	-210	-3707	878	3815	76	71	-94	240
3	1	7.94	-120	-4390	1177	4564	146	67	-4	22
	2	12.22	-87	-3529	990	3656	-14	65	129	259
	3	14.25	-82	-3071	877	3194	55	-20	156	-60
4	1	10.04	-192	-3987	1166	4158	33	-15	187	282
	2	13.15	-165	-3375	1017	3528	88	---	155	---
	3	15.99	-134	-2782	863	2915	14	20	34	41
5	1	9.14	-95	-4504	1144	4647	-19	33	-159	-146
	2	15.05	-46	-3293	887	3410	59	111	103	133
6	1	10.06	-27	-4436	988	4544	22	-15	124	212
	2	15.70	-27	-3262	763	3349	22	36	-12	161
	3	17.08	-19	-2948	694	3028	20	---	-73	---
	4	17.47	-21	-2859	671	2936	35	---	-157	---
	5	18.06	-12	-2716	641	2790	21	11	-172	-95
7	No Release									

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch X	Y	H	SRTC	Rocket Impact Coordinates X1	X2	Y1	Y2
Flight No. 5, 8 April 1971, MK-40 with 20° Short Bent Fins										
1	1C	12.42	-5	-3967	102	4098	12	74	193	273
	2C	18.46	-9	2657	713	2750	-22	-18	31	61
2	1	8.55	-88	-3978	977	4097	40	18	-165	-157
	2	13.03	-55	-3037	769	3133	86	118	-171	-111
3	1	6.17	-165	-3860	728	3931	-39	-29	-118	85
	2	9.45	-159	-3205	612	3266	50	60	-158	-182
	3	11.70	-131	-2733	535	2787	23	-5	115	205
4	1	10.52	-55	-4304	921	4401	-27	18	-157	90
	2	13.92	-50	-3613	785	3702	-15	--	-216	---
	3	15.64	-44	-3282	710	3358	24	3	-68	-39
	4	16.6	-41	-3064	669	3136	2	21	-142	44
	5	17.52	-35	-2868	635	2937	102	126	89	170
	---	18.41	---	-----	---	----	----	----	----	----
5	1	13.82	35	-3646	835	3740	-4	-32	-293	-65
	2	14.78	26	-3439	788	3528	49	55	-2	11
	3	16.06	23	-3164	730	3247	-16	-16	-304	-265
6	1	11.8	16	-3695	788	3754	11	38	-72	-36
	2	12.73	12	-3526	747	3604	-27	-18	-297	-186

(Continued)

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position of Launch				Rocket Impact Coordinates			
			X	Y	H	SRTC	X1	X2	Y1	Y2
Flight No. 6, 8 April 1971, MK-40 with 20° Short Bent Fins										
1	1C	806	-33	-3957	278	3966	81	-37	413	996
2	1C	11.02	-30	-3262	222	3269	35	14	-283	-186
3	1	7.04	-47	-3978	250	3986	32	94	33	212
	2	11.3	-38	-3044	230	3052	-36	40	-921	-842
4	1	8.7	-64	-3996	253	4004	-19	38	-737	38
	2	13.8	-48	-2870	218	2878	59	22	97	119
5	1	8.69	-23	-3580	256	3589	-7	-14	-746	-695
	2	12.8	-25	-2730	214	2718	-1	-9	-322	-139
6	1	6.87	-55	-3642	233	3649	32	39	-848	-873
	2	8.65	-60	-3240	224	3248	-4	9	803	-666
	3	11.02	-55	-2722	215	2731	-22	0	-150	-104
7	1	7.8	-43	-4094	238	4101	10	-20	-281	194
	2	11.23	-54	-3322	246	3331	-28	-54	-258	-122
	3	11.64	-57	-3233	249	3243	-40	-23	-483	-190
	4	12.11	-50	-3118	249	3128	-34	---	-120	----
	5	12.77	---	-----	---	----	---	---	----	----
8	1	10.62	-15	-3975	252	3982	-34	-16	-541	-211
	2	11.75	-14	-3719	252	3727	-24	-118	-150	799

(Continued)

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch X	Y	H	SRTC	Rocket Impact Coordinates X1	X2	Y1	Y2
Flight No. 7, 8 April 1971, MK-40 with 20° Short Bent Fins										
1	1C	5.28	-15	-4074	279	4083	30	83	-15	298
	2C	9.65	15	-3075	282	3087	66	11	219	248
2	1	15.16	-57	-2838	222	2847	-44	-8	-279	-183
	2	15.77	-54	-2703	22[illegible]	2712	38	7	-162	-240
	3	16.78	-51	-2484	[illegible]22	2493	28	-59	241	-93
	4	17.4	-48	-2346	216	2355	0	-12	-3	-54
	5	17.88	-48	-2235	213	2244	-17	---	455	----
3	1	8.89	-30	-4227	228	4233	-9	-25	110	290
	2	12.04	-21	-3540	225	3546	41	56	46	-297
	3	12.47	-18	-3432	231	3438	0	32	-104	-9
	4	13.02	-18	-3324	228	3330	-31	---	143	----
	5	13.47	-15	-3213	228	3219	-12	-46	267	193
	6	14.8	-18	-2919	231	2928	8	---	143	----
	7	15.4	-18	-2784	234	2793	33	1	255	404
4	1	12.3	-60	-3657	246	3663	-8	4	0	-390
	2	14.2	-57	-3243	243	3252	-9	20	151	234
	3	14.9	-54	-3087	240	3096	-15	-15	-247	28
	4	15.4	-51	-2973	237	2982	7	38	-4	369

(Continued)

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch				Rocket Impact Coordinates			
			X	Y	H	SRTC	X1	X2	Y1	Y2
	Flight No. 11, 5 May 1971, MK-40 with 20° Short Bent Fins									
1	1C	23.4	93	-3660	1456	3940	2	39	-16	-5
	2C	23.4	93	-3660	1456	3940	32	27	4	115
2	1	8.9	86	-4701	2041	5126	16	-43	-37	128
	2	9.8	84	-4534	1983	4949	-132	-90	-252	80
	3	11.7	79	-4165	1834	4552	-37	-83	13	180
	4	12.9	64	-3928	1744	4298	-6	-44	170	190
	5	13.9	63	-3712	1658	4066	-70	-90	-23	130
	6	14.8	52	-3513	1581	3853	-63	-52	-115	-56
	7	15.7	--	-----	3625	----	4	---	-24	----
	8	16.2	52	-3194	1451	3509	-35	---	30	----
	9	----	---	-----	----	----	15	---	34	----
	10	16.7	---	-----	----	3402	-61	---	65	----
3	1	11.9	-12	-3973	1701	4322	41	39	-102	-69
	2	12.7	-2	-3796	1630	4131	-20	2	-212	-191
	3	13.7	4	-3571	1540	3889	40	---	-1	----
	4	13.7	Start of Firing			3889	-34	---	-68	----
	5	----	---	-----	----	----	50	---	-27	----
	6	----	---	-----	----	----	2	---	-5	----
	7	15.1	6	-3257	1423	3554	63	---	134	----
	8	----	---	-----	----	----	41	---	137	----
	9	----	---	-----	----	----	11	---	173	----
	10	----	---	-----	----	----	7	---	198	----
	11	16.4	Stop of Firing			3223	-9	---	288	----

(Continued)

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch				Rocket Impact Coordinates			
			X	Y	H	SRTC	X1	X2	Y1	Y2
Flight No. 12, 5 May 1971, MK-40 with 20° Short Bent Fins										
1	1C	4.8	-13	-3459	284	3471	20	36	430	520
2	1C	18.0	-11	-1154	238	1178	74	-30	240	558
3	1C	5.0	-12	-4398	232	4404	-23	31	-747	-269
4	1	4.2	-- Start of Firing --			4604	26	---	-1104	----
	2	----	---	-----	---	----	44	---	-1086	----
	3	----	---	-----	---	----	-19	---	-936	----
	4	----	---	-----	---	----	-28	---	-879	----
	5	----	---	-----	---	----	-8	---	-744	----
	6	----	---	-----	---	----	-9	---	-735	----
	7	----	---	-----	---	----	39	---	-740	----
	8	----	---	-----	---	----	29	---	-586	----
	9	7.6	-19	-3937	243	3945	-34	---	-176	----
	10	----	---	-----	---	----	34	---	-109	----
	11	----	---	-----	---	----	2	---	-40	----
	12	----	---	-----	---	----	49	---	-20	----
	13	----	---	-----	---	----	-1	---	195	----
	14	----	---	-----	---	----	-66	---	294	----
	15	----	---	-----	---	----	-36	---	414	----
	16	----	---	-----	---	----	-54	---	466	----
	17	11.0	-- Stop of Firing --			3207	16	---	423	----

(Continued)

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch X	Y	H	SRTC	Rocket Impact Coordinates X1	X2	Y1	Y2
Flight 12, 5 May 1971, MK-40 with 20° Short Bent Fins										
5	1	5.5	-- Start of Firing --			4503	-6	---	-562	----
	2	----	---	-----	---	----	-23	---	-519	----
	3	----	---	-----	---	----	-14	---	-265	----
	4	----	---	-----	---	----	-3	---	-255	----
	5	----	---	-----	---	----	-18	---	-194	----
	6	----	---	-----	---	----	10	---	-136	----
	7	7.9	-34	-3817	287	3828	-18	---	-61	----
	8	----	---	-----	---	----	14	---	-28	----
	9	----	---	-----	---	----	12	---	97	----
	10	----	---	-----	---	----	-2	---	109	----
	11	----	---	-----	---	----	4	---	165	----
	12	----	---	-----	---	----	-6	---	435	----
	13	10.3	-- Stop of Firing --			3363	64	---	865	----

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch X	Y	H	SRTC	Rocket Impact Coordinates X1	X2	Y1	Y2
			Flight No. 13, 5 May 1971, Standard MK4							
1	1C	17.6	-- Start of Firing --			3601	-4	----	-179	----
	2C	18.8	227	-3148	1029	3320	77	----	-82	----
	3C	----	----	-----	----	----	53	----	127	----
	4C	19.9	-- Stop of Firing --			3060	145	----	174	----
2	1	10.7	1	-3685	1544	3995	-3	174	115	179
	2	11.2	-6	-3574	1493	3873	-1	21	-15	75
	3	12.1	-13	-3394	1439	3686	42	73	44	528
	4	13.9	-22	-2987	1292	3255	129	35	-154	466
	5	14.8	-31	-2772	1206	3023	89	58	-90	71
	6	15.5	-45	2602	1134	3839	-3	65	-160	-26
3	1	10.6	344	-3896	1636	4240	161	111	-375	231
	2	12.0	325	-3590	1519	3912	71	-72	-100	117
	3	13.6	295	-3217	1373	3510	-9	24	48	248
	4	14.6	272	-2984	1292	3263	142	-211	48	88
	5	15.3	254	-2806	1218	3069	-185	-59	49	207
	6	16.1	232	-2612	1145	2861	68	----	-292	----
	7	16.8	225	-2427	1064	2660	-25	----	-123	----
	8	16.8	----	-----	----	----	-120	-50	3	29
	9	17.5	205	-2244	974	2455	-112	-73	-170	-142
	10	18.3	185	-2046	89[illegible]	2241	-36	-31	-193	-116

(Continued)

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch X	Y	H	SRTC	Rocket Impact Coordinates X1	X2	Y1	Y2
	Flight No. 14, 5 May 1971, Standard MK4									
1	1C	8.1	-28	-3553	172	3557	-71	?	-945	3000 Approx.
2	1	4.9	-- Start of Firing --			4604	-40	---	1756	----
	2	----	---	-----	---	----	41	---	-982	----
	3	----	---	-----	---	----	19	---	-796	----
	4	----	---	-----	---	----	2	---	-787	----
	5	8.4	-40	-3867	155	3870	-46	---	-765	----
	6	----	---	-----	---	----	-26	---	-759	----
	7	----	---	-----	---	----	31	---	-444	----
	8	----	---	-----	---	----	-66	---	601	----
	9	----	---	-----	---	----	-161	---	-962	----
	10	11.8	-- Stop of Firing --			3150	-148	---	611	----
3	1	3.4	-- Start of Firing --			3309	-7	---	-1524	----
	2	----	---	-----	---	----	-44	---	-1180	----
	3	----	---	-----	---	----	44	---	-1111	----
	4	----	---	-----	---	----	-13	---	-1064	----
	5	----	---	-----	---	----	-32	---	-1020	----
	6	----	---	-----	---	----	45	---	-899	----
	7	----	---	-----	---	----	-1	---	-815	----
	8	4.3	31	-3109	178	3114	18	---	-464	----
	9	----	---	-----	---	----	90	---	-495	----
	10	----	---	-----	---	----	-35	---	-338	----
	11	----	---	-----	---	----	-106	---	-265	----
	12	----	---	-----	---	----	-38	---	-287	----
	13	----	---	-----	---	----	-15	---	132	----
	14	----	---	-----	---	----	31	---	356	----
	15	----	---	-----	---	----	30	---	436	----
	16	----	---	-----	---	----	57	---	596	----
	17	5.1	-- Stop of Firing --			2955	106	---	1522	----

(Continued)

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch X	Y	H	SRTC	Rocket Impact Coordinates XL	X2	Y1	Y2
		Flight No. 15, 7 May 1971, Standard MK40								
1	1	13.3	---	-----	----	----	75	---	-67	----
	2	14.0	Av.153	-3407	1543	3743	---	---	---	----
	3	14.6	---	-----	----	----	77	146	117	140
2	1	9.4	6	-4564	1739	4884	62	27	-115	-22
	2	11.2		-4240	1623	4540	66	63	-20	27
	3	12.6	11	-3969	1526	4252	25	---	61	----
	4	14.5	1[illegible]	-3583	1380	3840	-35	-23	-139	-69
	5	16.9	14	-3056	1187	3278	4	7	-85	-44
	6	18.[illegible]	14	-2758	1069	2958	-1	---	9	----
3	1	11.4	361	-399.7	1706	4361	36	41	-77	55
	2	12.5	335	-3813	1632	4161	47	50	-84	-12
	3	14.8	303	-3349	1448	3661	-80	-43	129	133
	4	15.8	279	-3136	1368	3433	-34	-46	-63	50
	5	16.4	256	-3015	1321	3302	-32	---	-58	----
	6	17.9	230	-2680	1171	2934	-67	-27	-127	-93
	7	----	---	-----	----	----	-11	---	-71	----
4	1	5.5	6	-7934	2528	8365	300	281	-597	-586
	2	15.4	-- Start of Firing --			6084	-20	---	-364	----
	3	Average	---	-----	----	----	-38	---	-338	----
	4	16.3	25	-5576	1810	5862	33	---	-199	----
	5	----	---	-----	----	----	30	---	-63	----
	6	17.1	-- Stop of Firing --			5638	24	---	97	----

(Continued)

TABLE A-2. TABULATION OF TEST DATA (CONT)

Pass No.	Pair Sequence	Time (Sec)	Helicopter Position at Launch X	Y	H	SRTC	Rocket Impact Coordinates X1	X2	Y1	Y2
	Flight No. 16, 7 May 1971, Standard MK40									
1 C	1C	6.8	-- Start of Firing --			3888	34	----	-139	----
	2C	8.5 Av.	---	-3526	214	3532	59	----	463	----
	3C	10.1	-- Stop of Firing --			3212	-117	----	922	----
2	1	4.2	-77	-4731	215	4736	-61	15	-751	-367
	2	6.6	-62	-4263	218	4268	-31	60	-578	-493
	3	7.8	-60	-4033		4039	37	-16	-160	91
	4	9.6	-46	-3683	217	3689	64	2	-920	-844
	5	10.3	-37	-3548	214	3554	-48	31	-572	-99
	6	11.4	-27	-3334	214	3340	42	40	-80	209
	7	12.4	-29	-3146	217	3153	-44	45	174	554
3	1	4.8	51	-4281	201	4285	87	-15	-92	335
	2	5.4	58	-4152	207	5157	55	46	238	-123
	3	5.9	43	-4072	206	4077	36	----	154	----
	4	7.3	60	-3768	211	3774	57	50	-834	-301
	5	----	---	-----	---	----	29	----	-74	----
	6	7.6	60	-3710	208	3716	55	----	238	----
	7	8.1	59	-3608	206	3614	73	109	130	-472
	8	8.4	64	-3545	205	3551	76	----	-176	----
	9	----	---	-----	---	----	70	----	-793	----
	10	----	---	-----	---	----	120	----	749	----
	11	----	---	-----	---	----	-23	----	1478	----